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(54) LUMINESCENT SCREEN

(57) Luminescent screen suitable for use, for example in cathode-ray tubes, electron microscopes, electron spectroscopes and for forming pictures in X-ray image intensifiers. The luminescent screen comprises a self-supporting monocrystalline body including a luminescent layer containing at least one activator. Preferably the luminescent surface portion 5 is grown on the substrate portion 4 by liquid phase epitaxy or formed by activators diffused into a monocrystalline body. The screen is exemplified by garnets of Y, Ga, Gd and Al activated by Tb, Tm, Eu, Ce or Nd.

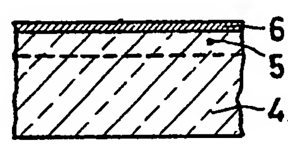

Fig.2

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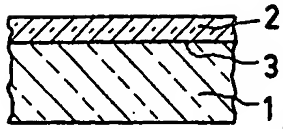

Fig.1

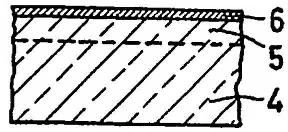

Fig.2

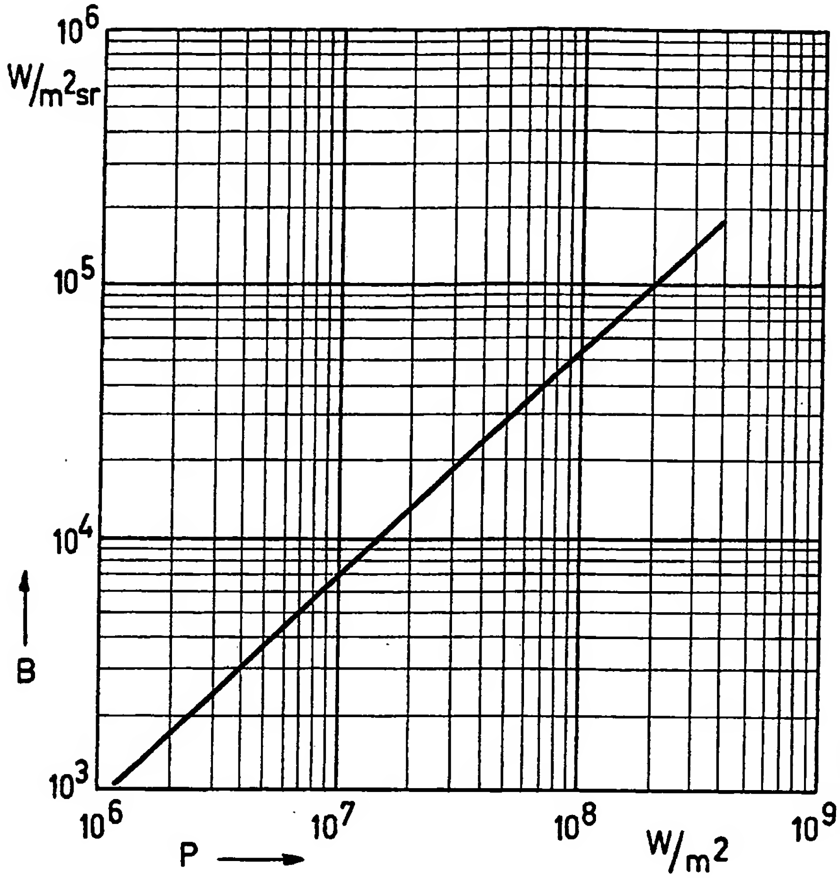

Fig.3

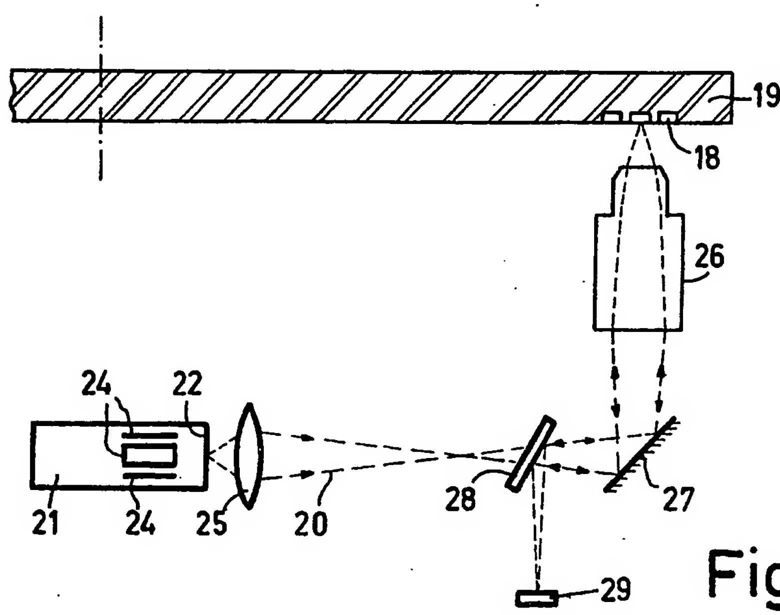

Fig.6

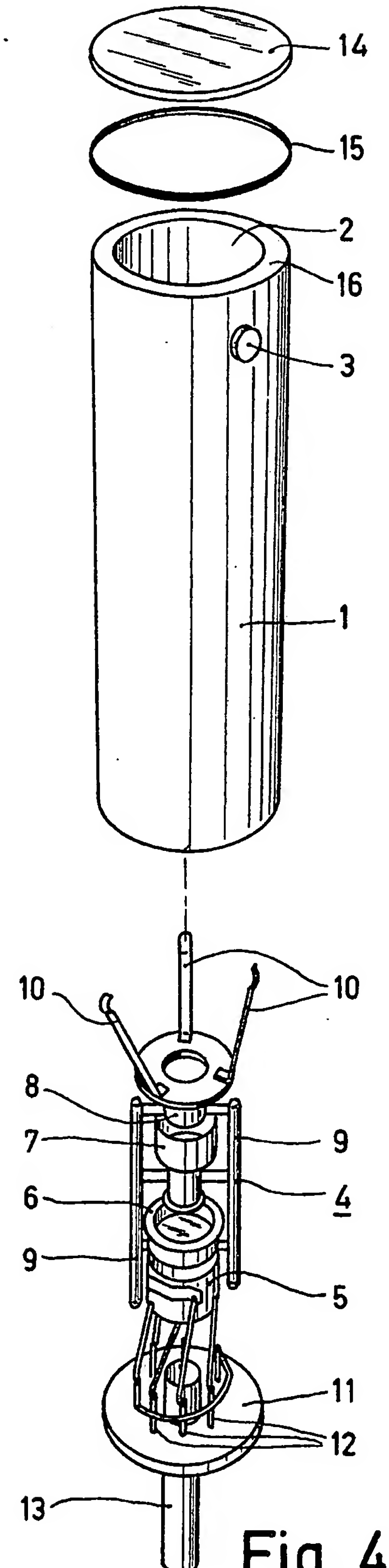

Fig. 4

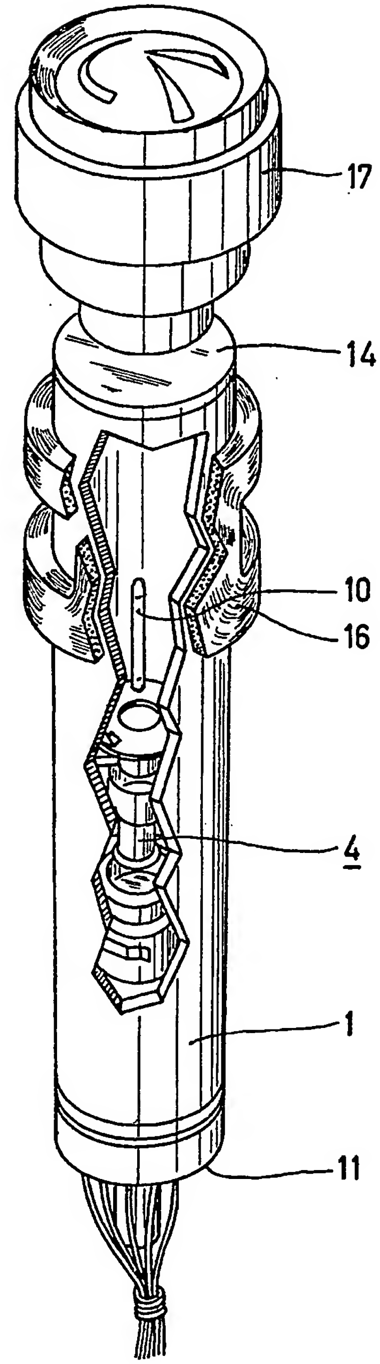

Fig. 5

SPECIFICATION

LUMINESCENT SCREEN

The invention relates to a luminescent screen comprising a substrate having a luminescent layer which has a monocrystalline structure and contains at least one activator. The invention also relates to a cathode-ray tube having such a luminescent screen.

German Patent Specification 810,108 discloses luminescent screens comprising a substrate bearing a monocrystalline layer containing at least one activator. Such luminescent screens are used in cathode-ray tubes, for example, television dispay tubes, in electron microscopes and electron spectroscopes and in forming pictures in X-ray devices, for example X-ray image intensifiers. German Patent Specification 810,108 discloses the formation of a monocrystalline luminescent screen by growing an activated monocrystalline layer on an auxiliary plate, for example, by vapour deposition or sublimation. The auxiliary plate preferably consists of a single crystal having the same or approximately the same grid dimensions. If desired, the auxiliary plate may be dissolved after bonding the activated monocrystalline layer to another substrate, for example a glass plate. A disadvantage of such luminescent screens is that in the case of high excitation energy, the thermal loadability for a number of applications is much too small and that diffuse reflections of the light generated in the activated layer occur at the interfaces of the substrate or the auxiliary plate with the activated layer.

It is also known to use powdered phosphors provided on a carrier as a luminescent screen. These screens also have only a low thermal loadability since the heat is insufficiently dissipated from the phosphor grains. Moreover, the resolving power of display screens is limited by the grain dimensions. As a result of the large number of grains, the specific surface area of the screen is large, which has a detrimental influence on the vacuum in a cathode ray tube.

Another construction in which the said diffuse reflections occur is disclosed in Netherlands Patent Specification 61,451 in which a luminescent screen is constructed from rod-shaped luminescent crystals which are provided on a carrier and which mutually are all substantially parallel and extend with their longitudinal axes perpendicular or approximately perpendicular to the major surface of the carrier so that the direction of the exciting rays is substantially parallel to the longitudinal axes of the crystals. A disadvantage of this construction is that the thermal loadability of the luminescent screen is too small for a number of applications. In addition the resolving power is limited by the dimensions of the individual crystal.

It is the object of the invention to provide a luminescent screen which has a high thermal loadability and a large resolving power and in which no diffuse reflections occur.

The invention provides a luminescent screen comprising a self-supporting monocrystalline body which includes a luminescent layer containing at least one activator. Since the substrate and the luminescent layer constitute one single crystal, there is no crystallographic interface and no grain structure and thus no diffuse reflections can occur. Furthermore, as a result of this construction, the heat dissipation of the luminescent layer to the substrate is good. The single crystal may be formed form a large number of substances, for example oxides, silicates, aluminates and gallates of the rare earth metals. However, the monocrystalline body preferably has the garnet crystal structure since in that case the heat dissipation from the luminescent layer is very good. The luminescent screen preferably has a thickness of from 0.3 to 2 mm in order to be self-supporting. The thickness of the luminescent layer is preferably from 1 to 6 μm, in particular approximately 2 μm, corresponding approximately to the depth of penetration of the electrons.

In one embodiment of a luminescent screen according to the invention the monocrytalline body is yttrium-gallium garnet and the luminescent layer comprises a total of from 0.2 to 5% by weight of terbium and/or thulium which serves as the activator. An efficient green luminescence is obtained with terbium and an efficient blue luminescence is obtained with thulium.

In another embodiment of a luminescent screen according to the invention, the monocrystalline body is gadolinium-gallium garnet and the luminescent layer comprises from 0.5 to 15% by weight of trivalent europium. In this manner an efficient red luminescence can be obtained.

In another embodiment of a luminescent screen according to the invention, the monocrystalline body is yttrium-aluminium garnet and the luminescent layer comprises a total of from 0.2 to 3% by weight of at least one of the activator elements cerium, terbium and neodymium. An efficient green luminescence is obtained with cerium and terbium and a substantially white luminescence is obtained with neodymium.

It is possible to manufacture a luminescent screen according to the invention by causing a quantity of activator to diffuse into the surface of a single crystal. However, this is a very slow process. It is alternatively possible to vapour-deposit a layer with activator succeeded by a thermal treatment.

However the activated layer is preferably grown by liquid phase epitaxy from a solution.

A luminescent screen according to the invention can be used in a cathode-ray tube for generating a very bright light spot. Said light spot may be used as a moving or as a stationary light source, or to form a very bright picture.

A very bright moving or stationary light source is necessary, for example, in a device for the optical scanning of an information track on an information carrier by means of a light beam as described in published Netherlands Patent Application 7,314,464 or in a film scanner as described in published Netherlands Patent

Application 6,706,095, which film scanner is used in converting film pictures into television pictures. Such a bright moving light source may alternatively be used as a scanning light source in a microscope.

The formation of very bright pictures takes place in projection television display tubes. In order to obtain a sufficiently bright picture, hitherto said tubes have had display screens of comparatively large dimensions. The picture generated on the screen having a diameter of, for example, 13 cm had to be very bright to enable a sufficient magnification of the picture upon projection. A cathode-ray tube according to the invention is very suitable for use in a projection television device because the good heat dissipation enables a small screen to be used with a very bright picture. It is possible, for example, to manufacture a luminescent screen having an area smaller than 20 cm^2, preferably smaller than 5 cm^2, in which the average power density of the irradiated light is larger than 0.1 W/cm^2, and in most cases is larger than 0.5 W/cm^2.

Some embodiments of the invention will now be described with reference to Figures 2 and 3 of the accompanying drawings, in which

Figure 1 is a diagrammatic sectional view of a part of a known luminescent screen.

Figure 2 is a diagrammatic sectional view of a part of a luminescent screen according to the present invention.

Figure 3 is a graph showing the brightness of a luminescent screen according to the invention,

Figure 4 is a partly perspective exploded view of a cathode-ray tube according to the invention,

Figure 5 is a partly perspective view of the cathode-ray tube of Figure 4 shown in an assembled state with part of the envelope shown broken away, and

Figure 6 shows diagrammatically a device for the optical scanning of record carriers.

Figure 1 shows a known monocrystalline luminescent screen having a rock salt (mineral kitchen salt) substrate 1 on which a layer of zinc sulphide 2 has been vapour-deposited after heating to approximately 175°C, which layer has been activated at approximately 350°C with lead or copper and has been annealed at the same temperature. The heat transfer from the layer 2 to the substrate 1 is insufficient for many applications and furthermore diffuse reflections of the generated light occur at the layer-substrate interface 3.

Figure 2 is a sectional view of a part of a monocrystalline luminescent screen according to the invention. In this case the substrate 4 consists of yttrium-aluminium garnet ($Y_3Al_5O_{12}$). A cerium-activated layer 5 of yttrium-aluminium garnet ($Y_{2.97}Ce_{0.03}Al_5O_{12}$) is grown on the substrate 4 by liquid phase epitaxy. In this manner one monocrystalline body is formed which in a surface layer contains cerium. Since no crystallographic interface is present between the cerium-activated layer 5 (above the broken line) and the non-activated substrate 4 (below the broken line), diffuse reflections cannot occur in the monocrystalline body. In this case an aluminium film 6 of 0.08μm thickness is provided over the cerium-activated layer 5 and reflects the light generated in the activated layer.

A number of properties of the $Y_3Al_5O_{12}$ substrate and the $Y_{2.97}Ce_{0.03}Al_5O_{12}$-layer used in this case are recorded in the following table:

TABLE

Substrate:	$Y_3Al_5O_{12}$
Structure:	cubic, A_0=12.001 Å
Hardness:	8–8.5 Mohs
Melting point:	2220 K
Thermal conductivity coefft.	0.13 W/cmK
Thermal expansion coefft.	7.5 × 10^{-6}/deg. C
Index of refraction:	1.84

Activated layer 5	$Y_{2.97}Ce_{0.03}Al_5O_{12}$
Cathode ray	
Energy efficiency:	3% (15 lm/W)
Decay time:	70 ns
Wavelength of the maximum emission:	555 nm
Extinguishing temperature:	580 K

The brightness of a luminescent screen shown in Figure 2 is illustrated in Figure 3 which is a graph in which the radiated radiance B in W/m^2 sr is plotted as a function of the power P in W/m^2 supplied by an electron beam. In this measurement, an electron beam was directed on such a luminescent screen with an energy of 15 kV and a current strength of 100 nA. The number of W/m^2 was varied by more or less focusing the electron beam and hence varying the area of the spot.

In the case of a luminescent screen having a powdered phosphor, as used hitherto the luminescent material becomes too hot with this supplied power. In addition, the phosphor is saturated and no longer radiates more light when the supplied power is increased. The values of the radiated radiance of known powdered phosphors is outside the region shown in Figure 3.

It has been found that the luminescent screen according to the invention does not become too

hot. The luminescent layer does not become too hot due to the very good thermal contact of said layer with the substrate with which the luminescent layer forms a single crystal.

Figure 4 is a perspective exploded view of a cathode ray tube having a luminescent screen according to the invention. An electron gun 4 is positioned inside a cylindrical envelope 1 of aluminium oxide which is provided internally with an electrically conductive coating 2 connected to an anode contact 3. Said electron gun 4 consists of a cathode (not shown) which is accommodated in the Wehnelt electrode 5 so as to be insulated and of a number of grids 6, 7 and 8. The electrodes of the electron gun 4 are connected together in the usual manner by means of glass assembly rods 9. The electron gun 4 has centring springs 10 at one end. The other end of the gun is secured to a base plate 11 having contact lead-throughs 12 and an exhaust tube 13. The other end of the envelope 1 is closed by a luminescent screen 14 which consists of gadolinium-gallium garnet and which is activated with europium on its side facing the electron gun 4. The thickness of the luminescent screen is 500μm and its diameter is 25 mm. The luminescent screen is coated with an aluminium film (not shown). The luminescent screen 14 is connected to the aluminium oxide envelope 1 by means of a thermo-compression bond. For that purpose, an aluminium ring 15 is used as a connection material between the edge 16 of the envelope 1 and the luminescent screen 14. The coefficient of thermal expansion of the aluminium oxide of the envelope and the coefficient of thermal expansion of the luminescent screen differ only slightly so that no undesired stresses occur as a result of thermal expansion. The deflection of the electron beam generated by the electron gun is obtained in the usual manner by means of magnetic deflection fields. However, it is alternatively possible to use electrostatic deflection, since said small display screens only require a small deflection.

Figure 5 is a perspective view of the tube shown in Figure 4 with part of the envelope shown broken away, used as a component of a projection television device. Deflection coils 16 are arranged around the envelope 1. The bright picture on the luminescent screen 14 is projected on a projection screen (not shown) by means of a lens system 17.

Figure 6 shows diagrammatically a device for the optical scanning of an information track 18 on an information carrier 19 by means of a light beam 20 which is generated by means of a cathode-ray tube 21 including a luminescent screen according to the invention. The manners in which said scanning may be carried out are explicitly described in published Netherlands Patent Application 7,314,464. The great advantage of using a cathode-ray tube with a luminescent screen according to the invention is the brightness of the image on the screen, as a result of which losses of optical elements become less important. By means of the cathode-ray tube 21, a bright light spot 23 is generated on the luminescent screen 22, which spot can be moved over the whole screen 22 by means of voltages applied across the deflection plates 24. By means of lenses 25 and 26, the light dot is reproduced on the rotating disc-shaped record carrier 19. The light reflected by the information carrier is reproduced on the photocell 29 *via* lens 26 and mirrors 27 and 28. Mirror 28 is a semi-permeable mirror. The reflected light is intensity-modulated by the rotating record carrier 19 with information and thus comprises the information for the record carrier 19. Displacements of the light spot 23 on the record carrier 19 can be obtained by displacing the light spot 23 on the luminescent screen 22. Intensity losses occur at the various optical elements, for example at the semi-permeable mirror 24. Therefore the use of a bright light source is necessary. A cathode-ray tube having a luminescent screen according to the invention is very suitable for this purpose.

CLAIMS

1. A luminescent screen comprising a self-supporting monocrystalline body which includes a luminescent layer containing at least one activator.

2. A luminescent screen as claimed in Claim 1, wherein the monocrystalline body has a garnet crystal structure.

3. A luminescent screen as claimed in Claim 2, wherein the monocrystalline body is yttrium-gallium garnet and the luminescent layer contains a total of from 0.2 to 5% by weight of terbium and/or thulium.

4. A luminescent screen is claimed in Claim 2, wherein the monocrytsalline body is gadolinium-gallium garnet and the luminescent layer from 0.5 to 15% by weight of trivalent europium.

5. A luminescent screen as claimed in Claim 2, wherein the monocrystalline body is yttrium-aluminium garnet and the luminescent layer comprises a total of from 0.2 to 3% by weight of one or more of the activator elements cerium, neodymium and terbium.

6. A luminescent screen as claimed in any preceding Claim, wherein the thickness of the luminescent screen is between 0.3mm and 2mm.

7. A luminescent screen as claimed in any preceding Claim, wherein the luminescent layer is from 1 to 6μm thick.

8. A luminescent screen as claimed in any preceding Claim, wherein the luminescent layer has been grown by liquid phase epitaxy from a solution.

9. A luminescent screen comprising a self-supporting monocrystalline body which includes a luminescent layer containing at least one activator, substantially as herein described with reference to Figure 2 of the accompanying drawings.

10. A cathode-ray tube having a luminescent screen as claimed in any preceding Claim.

11. Apparatus for the optical scanning of an information track on an information carrier by means of a light beam, which apparatus includes a cathode-ray tube as claimed in Claim 10 whereby the light beam is generated.

12. A projection television apparatus comprising optical means for displaying a bright picture on a projection screen, which apparatus includes a cathode-ray tube as claimed in Claim 10 whereby the light beam is generated.

13. A projection television apparatus as claimed in Claim 12, wherein the display screen surface area is smaller than $20cm^2$ and the average power density of the radiated light is larger than 0.1 W/cm^2.

14. A projection television apparatus as claimed in Claim 13, wherein the display screen surface area is smaller than 5 cm^2 and the average power density of the radiated light is larger than 0.5 W/cm^2.

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